This Senior Thesis Is A Partial Fullfillment

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Development

Of A

Project On Hydrology

Using The

Mammoth Cave Kentucky Area

As An

Example

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Introduction

This senior thesis was an attempt to develop a useful project on hydrology for possible use by Dr. J.O. Fuller in introductory geology classes. A project is a learning guide for the student based on problem solving. For example, a student may be given a map illustrating particular geologic structures. The student then answers questions about the features they see, drawn from information received in lecture sessions and from the text. The project described in this thesis concerns hydrology, in particular surface and subterranean features developed by erosion and movement of water, using the Mammoth Cave Kentucky area as an example. Questions in the project are based on features easily seen on a 15 minute raised topographic sheet of the Mammoth Cave Kentucky area.

Geology of the Area

In order to develop an accurate and informative project, it was necessary to first understand the local geology of the area of Kentucky used in the project. The geology, particularly of Edmonson County, the location of Mammoth Cave, is relatively simple. It is well established that much of the North American interior, including Kentucky, was covered by a broad shallow sea during much of the Paleozoic. The seas did not leave this area until the end of the Paleozoic. The majority of the rocks exposed today in Kentucky are from the Carboniferous Period (Weller, 1927). These rocks indicate that two major types of sedimentation took place during the Mississippian and the Pennsylvanian.

The majority of sediments deposited in the Mississippian were limy muds. The type of rocks exposed today from this sedimentation are very pure, fossiliferous marine limestones (Weller, 1927). These limestones are finely to coarsely crystalline, and contain little or no sand and mud. Towards the end of the Mississippian, the rocks indicate that conditions of sedimentation were changing. That is, Upper Mississippian rocks begin to contain more sandstones which are well sorted medium grained, well indurated rocks (Weller, 1927). The end of the Mississippian is marked by a major unconformity in the rocks. Sedimentation had ceased, and stream channels began to cut deeply into the Mississippian sediments. Pennsylvanian rocks are characterized by cyclothems, a cycle of deposition containing a fluvial deposit, a coalified plant sequence, and a marine limestone or shale deposit (Weller, 1927). This type of cycle in the rocks indicates that during the Pennsylvanian, the exposed land surface was very near sea level. The area would have been above sea level, perhaps it was a swampy area or a marsh, with abundant plant life. Occasionally the sea would rise and the land would be inundated with water (Weller,1927). Clastic rocks make up a very large portion of Pennsylvanian strata also (Haynes, 1964). These consist of conglomerates, sandstones, and siltstones, the materials of which were derived further east from the area undergoing mountain building.

Minor unconformities within the Mississippian and Pennsylvanian strata indicate periods of minor uplifts and erosion.

Faulting and folding resulting from the Appalachian Orogeny further east are present in central Kentucky (Weller, 1927). However these structures are relatively minor, few in number, and do not seem to have any great effect on the erosion features seen today in Mammoth Cave.

Erosional Features

Since the Paleozoic, the interior of North America has never been resubmerged. The time since then has been a period of uplift and erosion. A major period of uplift occurred in the late Cretaceous, causing rejuvenation of streams flowing across the land (Weller, 1927). This uplift, coupled with the following Tertiary erosion caused the development of many of the features seen today in central Kentucky (Palmer, 1981).

The area of Kentucky used as the subject for the project is divided roughly into two topographic areas. The Chester Upland to the north, and the Pennyroyal Plateau to the south (Palmer, 1981). The Chester Escarpment is the boundary separating the two. The Chester Upland is characterized by numerous narrow, flat topped ridges, and steep limestone floored valleys (Palmer, 1981). The ridges are capped with erosion resistant late Mississippian and early Pennsylvanian sandstones (Haynes, 1964). These sandstones have formed a protectove barrier for the more easily eroded limestones beneath them.

The Pennyroyal Plateau has no protective resistant sandstone. As a result, the limestone is subject to erosion, and numerous sink holes dot the area, and streams often end abruptly where sink holes have developed in their channels (Haynes, 1964).

Where the northern part is characterized by steep ridges and narrow valleys, the southern plateau is a broad expanse of nearly level ground. See figure 1 for a generalized cross section of this area.

Prior to the Cretaceous uplift, the entire area had been eroded down to a level peneplain. The Green River was the primary stream draining this peneplain, and it had developed numerous meanders along its course. This is of course a typical pattern of a river at or near sea level, which instead of actively eroding downward, is now expending most of its energy transporting sediments. Following the Cretaceous uplift however, the Green River and its tributaries were rejuvenated. They began to once more actively erode and downcut the peneplain as they readjusted to the new base level. The uplift and subsequent rejuvenation has resulted in the Green River becoming entrenched within its course. Extensive erosion has produced the narrow flat topped ridges, carved out from the former peneplain.

Kentucky Caverns

The Mammoth Cave Kentucky area is the location of the most extensive system of cave passages in the world. The explanation of the development of the caves, and their features is very involved. The project itself placed no particular emphasis on the caves, in view of the fact that the project is for introductory courses. However, the caverns are an important feature of hydrological processes, and as such, they warrant a more detailed study in this paper.

Regional Setting

As mentioned before, this area of Kentucky is characterized by the hilly Chester Upland to the north, and the flat Pennyroyal Plateau to the south. The Flint Mammoth Ridge Caves are all located within the Chester Upland. The rock strata of this area of Kentucky dip very gently to the northwest, no more than one or two degrees (Palmer, 1981). Strata at the southeast are therefore at a higher elevation. This is one reason for the development of the Pennyroyal Plateau (Palmer, 1981). Being at a higher elevation than the strata of the Chester Upland, its insoluble layers of rock were stripped away more quickly. As the Chester or Dripping Springs Escarpment is eroded northward, isolated remnants of the limestones with their cap of sandstone are left on the Pennyroyal Plateau.

The northwesterly dip is due to the fact that these strata are located on the southeast edge of a large shallow basin, known as the Illinois Basin (Palmer, 1981). The contact of the limestones and sandstones becomes lower to the north, just the opposite of the higher elevation of the contact to the south. Because of this, in a northerly direction, the amount of the limestone exposed at the surface decreases, at the same time the sandstones begin to thicken. This results in decreasing the amount of water flow through the limestones, thus caves become less frequent the farther north one travels (Palmer, 1981). The cave area dies out near Indianapolis, Indiana (Palmer, 1981). To the east of Mammoth Cave, the limestones have a higher content of sandstone and shale, thus limiting the formation of caves in that direction. South of this area of Kentucky, the limestone rocks are covered by thick sequences of younger, insoluble rock (Palmer, 1981).

Locally, the limits of the cave system are defined in a northerly direction by the presence of the Green River. That is, the Green River is the stream receiving the underground water which travels through the caves and forms them. Therefore, there are no continous passages of caves beneath the Green River, from the south to the north (Palmer, 1981). There are however, caves scattered throughout the Kentucky area, but they are isolated spots, and are not connected into the Flint Mammoth Ridge Cave System. The Chester Escarpment is the southern boundary of explorable cave passages. This distinction is made because the Pennyroyal Plateau is also honeycombed with many caves, though much smaller in size. The caves of the Pennyroyal are so close to the surface of the land that they often collapse in on themselves, forming sinkholes. Also, they are very wet, making them unsuitable for exploration (Palmer, 1981).

All of the extensive, explorable cave systems are located within the Chester Upland (Palmer, 1981). There the caves are protected from erosion by the overlying erosion resistant sandstones and shales of the ridges. Between the narrow ridges are the limestone floored valleys. These are often dry, having had their water flow diverted underground once the soluble limestone was reached (Palmer, 1981).

An area where the surface features have been produced by solution is said to have karst topography. The Pennyroyal Plateau is such an area. As mentioned before, it is a level plain several hundred feet below the elevation of the Chester

Upland to the north. The Pennyroyal is a limestone floored plain, and it is liberally dotted with sinkholes. Sinkholes are formed from the solution of limestone within cracks and joints of the rock, and then subsequent collapse of the soil and bedrock into the opening. Sometimes, they also result from the roof of a cave collapsing in on itself. Some of the sinkholes in this area are quite large, up to several hundred feet wide, and more than one hundred feet deep (Palmer, 1981). Due to the caves within the underlying limestone and the sinkholes, which serve as drainage basins into the limestone, precipitation disappears before surface streams can form.

Small streams do occur in parts of the Pennyroyal Plateau, farthest from the existing major river valleys (Palmer, 1981). These are called sinking streams, because they disappear underground not far from where they originated (Palmer, 1981). Possibly they are remnants of streams which long ago crossed the Pennyroyal to empty into major rivers (Palmer, 1981). As major rivers eroded into their channels, they did so at a faster rate than what the smaller streams could maintain (Palmer, 1981). The smaller ones were then diverted underground in a continous effort to reach the new base level. The surface parts of these sinking streams are located in areas where the limestone contains a higher percentage of sandstones and shales (Palmer, 1981).

Location of the Cave Systems

The ridges in the Chester Upland which are still overlain by the insoluble rocks are the locations for the major interconnected cave passages. Three of the ridges are especially important. The centrally located ridge is that of Mammoth Cave, it extends about four miles in a southeast-northwest direction. The cave extends the entire length of the ridge with its interconnecting passages forming nearly one hundred miles of the total two hundred and fifteen miles of connected passages (Palmer, 1981). Joppa Ridge, southwest of Mammoth Ridge is a longer ridge, but trends approximately the same direction. These two ridges are separated from each other by the dry Doyel Valley, a limestone floored valley (Haynes, 1964). There are several miles of caves beneath Joppa Ridge, and in 1979, Mammoth Cave was connected to the largest of these (Palmer, 1981). Flint Ridge is northwest of Mammoth Ridge, it is also larger than Mammoth Ridge, and trends in a southeast-northwest direction. The cave passages in Flint Ridge are slightly less than one hundred miles in distance, but this system is connected with the cave system of Mammoth Cave (Palmer, 1981). Another dry valley, the Houchins Valley, is located between these two ridges. Many passages from both cave systems extend under Houchins Valley, but only one has ever been found that connects the two systems (Palmer, 1981).

Most of the pleasant, dry, easily explored passages are within the ridges (Palmer, 1981). There they are protected by the insoluble sandstones. Beneath the limestone valleys, such as the Houchins, the passages are wet, and much smaller (Palmer, 1981). These passages have no sandstone to protect them from erosion, and they are often destroyed by collapse of their ceilings (Palmer, 1981).

The Rock Units of Mammoth Cave

The caverns of Mammoth Kentucky are contained within three of the Mississippian limestone formations. These three are the St. Louis Formation, the Ste. Genevieve Formation, and the Girkin Formation (Palmer, 1981). The St. Louis is the oldest, and the lowest formation, the Girkin is the youngest, and the highest formation of these three units (Haynes, 1964). The different levels of the caves combined together extend through a total thickness of approximately three hundred feet of these limestones (Palmer, 1981). See figure 2 for a stratigraphic cross-section and given thicknesses of the area formations.

The St. Louis has a thickness totaling slightly over two hundred feet, but only the upper part of the unit is exposed. The lower St. Louis contains a large number of cherty nodules and thin beds, it is this feature which distinguishes the lower unit from the upper unit (Palmer, 1981). The upper part of the formation contains very little chert, and has a typical brown coloring produced by weathering (Palmer, 1981). The lowest levels of the caves are found in this formation (Palmer, 1981).

Overlying the St. Louis is the Ste. Genevieve Limestone, which is approximately one hundred ten to one hundred twenty feet thick (Palmer, 1981). The lowermost beds of this formation consist mostly of a light gray limestone and dolomite, but in the uppermost beds, the limestone is interbedded with thin beds of dark colored, granular limestone. These silty layers weather more readily and form deeply carved out areas between the purer limestone layers (Palmer, 1981). The majority of the cave passages are found in this level.

The Girkin is the uppermost formation of these three. It is made up of a light gray limestone and contains some dolomite (Palmer, 1981). This unit ranges in thickness from one hundred thirty-five to one hundred forty feet (Palmer, 1981). Towards the top of this formation, it begins to contain a progressively higher content of shale (Palmer, 1981).

These three limestone formations are the location of the entire Flint Mammoth Cave System, but the overlying sandstones are just as important. If it were not for these massive beds, the limestones would have no protection from erosion, and much of the cave would be destroyed. Of these sandstones, the Big Clifty Formation is the youngest, it is a rock unit fifty to one hundred feet thick (Palmer, 1981). The Big Clifty consists of shales and siltstones near the contact with the Girkin, and grades upwards to sandstones (Hyanes, 1964).

Solution of the Limestone

The actual "carving out" of a cave is by solution of limestone. Kentucky receives approximately forty-five inches of precipitation a year (Weller, 1927). This is more than enough water to continue active development of the caves. The precipitation combines with carbon dioxide in the air, or in the ground to form carbonic acid. Limestone is readily dissolved by carbonic acid, and the result is calcium and bicarbonate ions which are carried away in solution. This process is called carbonation and is represented by the following formulas:

$$H_2O + CO_2 \quad H_2CO_3$$

$$CaCO_3 + H_2CO_3 \quad Ca^{++} + 2HCO_3^-$$

The amount of limestone which is dissolved is dependent on the amount of carbon dioxide the water combined with, in other words, the strength of the carbonic acid. The solution of the limestone, or enlargement of caves occurs most easily along cracks or joints already present in the rock (Weller, 1927).

In an idealized situation, the water table controls the movement of the water. Water soaking into the ground will generally move vertically through the zone of aeration to the zone of saturation. Once this has been reached, the water begins to move laterally along bedding planes or cracks in the rock. But realistically, the movement of the water is also controlled by the occurrence of cracks, folds, joints, bedding planes, and faults. Water will travel along the path which offers the least resistance to its travel. So water in the zone of aeration may travel horizontally along a crack or bedding plane before it finally reaches the zone of saturation (Palmer, 1981). Many passages, indeed the majority of passages, follow the same rock layers for long distances (Palmer, 1981). That is, they follow bedding planes and do not cut across beds, unless it runs into a fault or large joint (Palmer, 1981).

The water which forms the caves comes from Kentucky's large amount of precipitation. It has a definite pattern of movement through the caves. Water soaks through the limestone floored valleys and enters directly into the cave system (Palmer, 1981). Much of the water in the caves also originates from streams draining the Pennyroyal as it travels towards the Green River. During times of higher water, such as in the spring, the Green River itself backs up into the lower cave passages (Palmer, 1981). The flood waters not only speed up solution of the limestone and therefore enlargement of the lower passages, but they deposit sediment in the caves as well.

Types of Cave Passages

Though the caves all seem unique from one another, there are three basic types of passages (Palmer, 1981).

Tubular passages are tunnels which have round or elliptical cross sections (Palmer, 1981). They come in a variety of sizes, some are as wide as one hundred feet and up to thirty feet high. Tubes are in the zone of saturation when they form, they are completely filled with water (Palmer, 1981). They tend to be very horizontal as the water generally moves laterally along bedding planes, dissolving the limestone as it travels (Palmer, 1981). As the water table lowers, perhaps due to the downward erosion of the Green River, these tubular passages are generally abandoned (Palmer, 1981).

Some of the most spectacular types of passages are the canyon passages. These are formed above the Green River, that is, above the water table by underground streams (Palmer, 1981). These streams follow the dip of the limestone beds and erode their channels downward. They are higher than they are wide, with their walls being roughly the same distance from each other at the top as they are at the bottom (Palmer, 1981). They can reach enormous sizes, up to one hundred feet high and fifty feet wide (Palmer, 1981). As the channels erode downward, they may cut a channel which is more steeply inclined than the regional dip, as they are controlled by the water table. The ceiling however generally follows the regional dip of the rocks (Palmer, 1981).

The last distinctive type of cave passage is the vertical shaft. These are also formed in the zone of aeration by water flowing or even dripping downward along vertical joints or cracks (Palmer, 1981). They are shaped like a well, with a roughly circular outline. The sides are usually smooth, with openings along its side where former drains use to be (Palmer, 1981). These shafts may be quite deep, up to two hundred feet, and approximately thirty feet wide (Palmer, 1981). They are usually emptied by a drain which has developed above the bottom by water moving along cracks in the rock. As the bottom of the tube erodes downward, these drains are usually abandoned, and new ones form farther down (Palmer, 1981). Some of these abandoned drains are big enough to explore and occasionally have led cave explorers to previously unexplored passages (Palmer, 1981).

The entire system of caves is an enormous network of canyons, tubes, and shafts which may connect up with each other or merge with seemingly random patterns. Cave passages all become larger, or join up with other passages in a downstream direction (Palmer, 1981).

The size of the passages which are formed are undisputedly linked to former levels of the Green River. There are three main levels of cave passages, and these roughly correspond to three former levels of the Green River (Palmer, 1981). This theory is strongly supported by the appearance of the Pennyroyal Plateau. Such a flat area as this is thought to have resulted from the surface streams remaining at the same level for a long time. The erosion of the surrounding limestone strata by the streams resulted in the land being worn down almost to the level of the river (Palmer, 1981). Theoretically then, underground rivers remain at roughly the same level, without constantly having to adjust to a new base level, and therefore the caverns are enlarged for a much longer time (Palmer, 1981). With this theory in mind, it is to be expected that the largest cave passages in the Flint Mammoth Cave System are at approximately the same level as parts of the Pennyroyal Plateau, as indeed they are (Palmer, 1981).

Effect of Geologic Structure

Idealistically the level of a cave passage is controlled by the Green River's elevation. However, many other factors enter into the process. As already mentioned, partings and joints influence the development of a cave level. The water itself influences the development of passages by the length of time water flow occurs. The amount and the velocity of the water flow is also very important (Palmer, 1981).

Likewise, the dip of the rocks influences the development of passages. This is because water in the zone of aeration tends to flow down dip along cracks in the rock (Palmer, 1981). The dip is affected by all sorts of minor structures such as folds and faults, this causes cave passages to be oriented in all directions, even opposite to the local dip (Palmer, 1981).

Tubes are often parallel to the regional strike (Palmer, 1981). Since they form in the zone of saturation, they flow along the path which offers the least amount of resistance, which is commonly the strike of the beds (Palmer, 1981). But, even these structures are affected by irregularities in the beds, or the occurrence of a fault or joint which can divert the concentration of water flow (Palmer, 1981).

Cave Deposits and Decorations

The movement of underground water not only produced the caves in this area, but it produced within the caverns its own special artwork. It carved some unique shapes out of the limestone as well as formed some others by the deposition of calcium carbonate. Samples of this artwork are widely varied, but only a few of the most common ones will be mentioned.

Scallops are hollowed out "spoon shaped" areas along the interior of the cavern (Palmer, 1981). These structures can indicate the direction of water flow, as their steep sides face in a downstream direction (Palmer, 1981). Not only do scallops indicate the direction in which water was flowing, they also give an idea of the velocity of flow (Palmer, 1981). The velocity of the water can be inferred from the length of the scallop. As a general rule, the higher the velocity of the water, the smaller the scallop which forms (Palmer, 1981).

Solution pockets are another feature often seen in the cave, and they are pretty much just what their name implies. They are an area where a hole or crack has been formed by limestone solution, they are usually only a maximum of ten feet deep, and ten feet wide (Palmer, 1981). Normally they form at the location of a joint, naturally if the water had continued to flow in this cave, this solution pocket could well have formed another cave passage (Palmer, 1981).

Another interesting type of cave sculpture is the anastomose. These form in the ceilings by dissolution of limestone along bedding planes (Palmer, 1981). Characteristically, they are intricate, winding features, ranging from a very thin, shallow one to structures big enough for a person to crawl through (Palmer, 1981). They have a semicircular to circular cross section, unless the bed underlying them drops away to expose them (Palmer, 1981). Anastomoses form either from a former solution channel, or where water is injected into partings of the rock by pressure, at or near the water table (Palmer, 1981).

Thickly bedded limestones often have flutes, or symmetrical furrows cut into them. These are formed by vertically moving water (Palmer, 1981). Bedding planes will interfere with their development, so they tend to develop most extensively in the thickly bedded limestones (Palmer, 1981). Flutes often line the walls of vertical shafts (Palmer, 1981).

In addition to carving out some interestingly sculptured forms, water will also form some beautiful structures by deposition of calcium carbonate. This usually occurs in caves which are well ventilated by a surface entrance, passages of this sort tend to be depleted in carbon dioxide (Palmer, 1981). As the water passes through this type of cavern, it gives up some of its carbon dioxide, the water is then not able to carry as much calcium carbonate in solution, so it deposits it as travertine (Palmer, 1981). There are a wide variety of shapes formed in this way. Stalactites are cone-like structures built from the ceiling down, in places where the water has evaporated, leaving behind calcium carbonate. Water that drips onto the floor and then evaporates will build up deposits of calcium carbonate, these are the stalagmites. These two structures may become large enough to join together, forming what is called a column (Palmer, 1981).

Ledges within the cave are often decorated with layers of flowstone. These structures look like a waterfall which has been frozen in an instant's time, as the name Frozen Niagara implies (Palmer, 1981). There are several other different shapes of cave deposits, such as helictites, which form in caves where the amount of water entering it is very small (Palmer, 1981). As the water evaporates, the calcium carbonate left behind randomly builds up tubular looking deposits (Palmer, 1981).

Standing pools of water within the caves often have minerals build up around their rims, hence it is called rimstone. These may become large enough to act as a dam around the pool, if the water level ever rises (Palmer, 1981).

Cave popcorn is a mineral deposit that naturally, looks like popcorn. This is frequently found on the floor or walls around a waterfall where the water has continously splashed out on the surrounding rock (Palmer, 1981).

Some caverns are very dry, and a different kind of mineral deposit forms in these. Gypsum is only deposited in very dry passages. Water carrying gypsum in solution derived possibly from the weathering of iron sulfide, enters one of these dry caverns, and is almost immediately evaporated (Palmer, 1981). The gypsum left behind often builds up layers to form very delicate flower like structures, hence the name, gypsum flowers (Palmer, 1981).

Nitrate deposits are also very common in Mammoth Cave, in fact during the War of 1812, these nitrates became the primary source for the manufacture of gunpowder for the United States (Weller, 1927). Remains of this once important industry, such as mining tools and mixing vats are still present within Mammoth Cave. At any rate, nitrates are deposited by water that has traveled through organic material (Palmer, 1981).

There are many interesting features to be seen within the caves, both mechanical structures, and mineral deposits. And these will change from year to year as more deposits or limestone is added or taken away. Perhaps the most important thing to keep in mind is that the development of the caves is not a static occurrence. In other words, it is still a very active process, and in future years, perhaps there will be more passages to explore, and more interesting structures to delight in.

Conclusion

The preceding pages describe some of the geologic features of Kentucky developed by erosion and the solution of limestone by water. Based on some of these features, a project was developed to aid in teaching introductory geology students some basic geologic processes. For the result of this work, see the accompanying, completed project.

It is hoped that this project, along with others already in existence, will serve three main purposes. One has already been mentioned above, and that is to introduce some basic geologic processes to non geology majors. In addition, it is believed that a project facilitates learning for the student, and helps make the newly learned material easier to retain. This is based upon the hypothesis that actually working on a concrete, visible example on new material will enable it to be better remembered than a brief explanation out of a text book.

The third purpose is perhaps not so obvious. Students work on these projects in small groups of five or six. In the large classes common to today's colleges, this enables the instructor to become better acquainted with the students. It also exposes the students to working in group situations, hopefully teaching them how to be compatible with and work with other people. For some of these students, this may be the first time they ever had to work with other people. It is felt that this is an important ability, because many jobs in today's job market entail working with small groups. Hopefully then, the projects will serve as a learning aid, both scientifically and socially.

APPENDIX

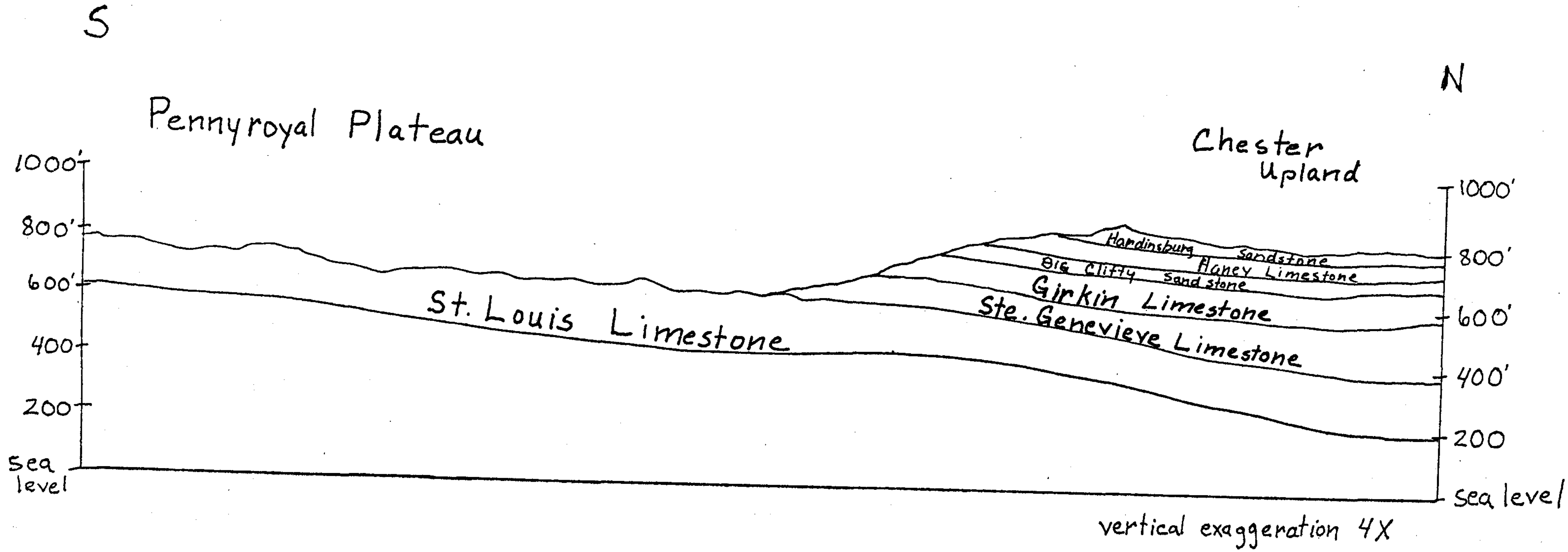

Figure 1

Generalized Cross Section of the Mammoth Cave Kentucky Area (adapted from Richards, 1964)

Stratigraphic Section of The Mammoth Cave Kentucky Area.

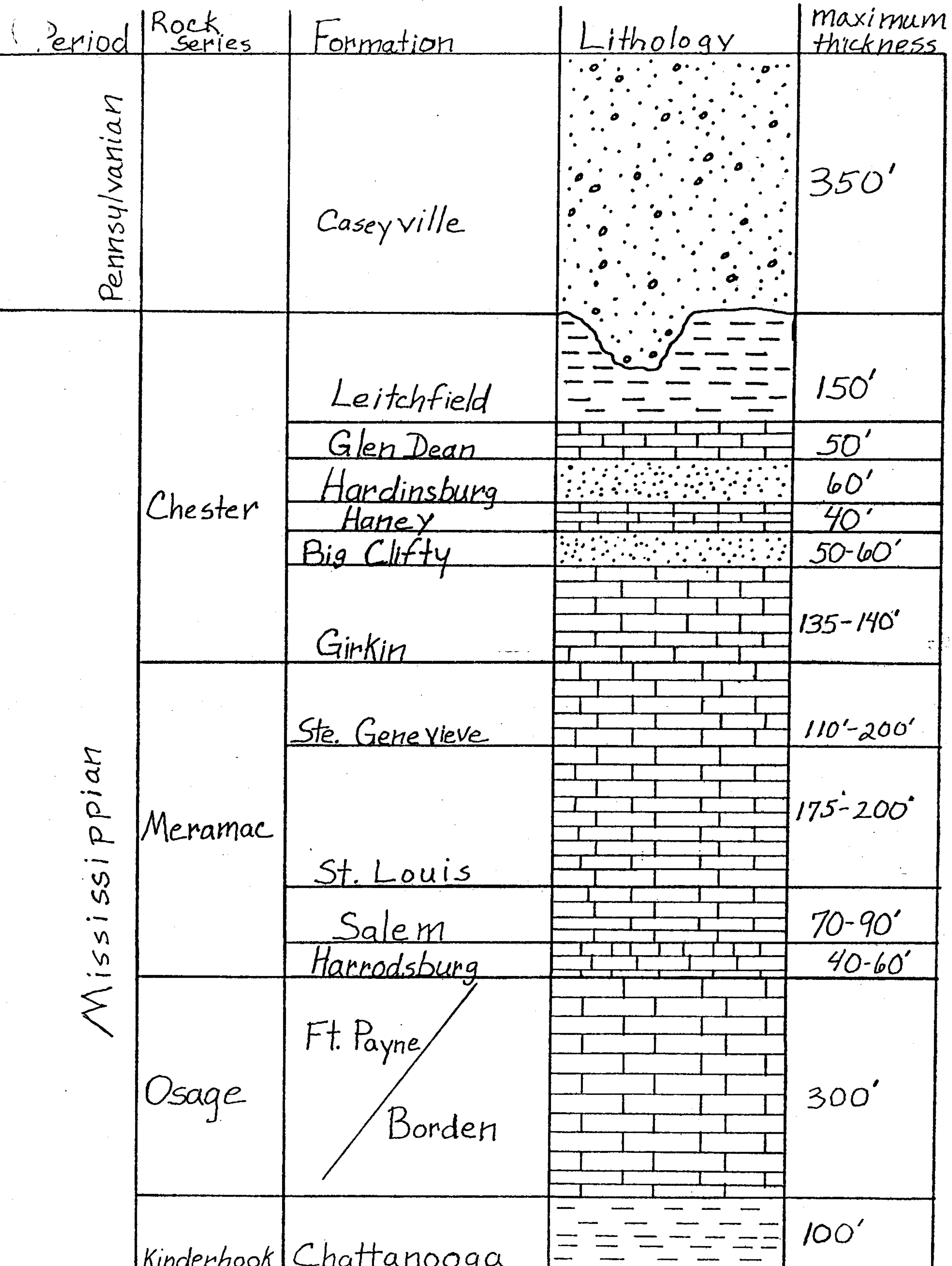

Figure 2

1" = 200'

(adapted from Haynes, 1964).

Name ______________________

Group______________________

Hydrology

The date was September 9, 1972. After 14½ hours in the cave the explorers were becoming discouraged. It looked like another attempt to find a connecting passage between Flint Ridge Cave and Mammoth Cave was once again doomed. The expedition leader explored ahead of the others in an unpromising looking crawlspace. And then,

> "...He stood, stunned. The walls had opened out. He had come into a tremendous void, with a lake ahead... and in the distance was a gleaming tourist handrail...!"

It was finally done, after decades of exploration. This expedition had found a connection between the Flint Ridge Cave System and the Mammoth Ridge Cave System. Kentucky was finally able to lay claim to the longest cave in the world, an incredible 144.4 miles! Since 1972, the number of explored interconnected passages has increased this number to 215 miles.

How was this marvelous system of caves formed? As you will find out in this project, caves are a direct result of geologic processes, a combination of the composition of the local rocks and the movement of ground water. But first, let's look at some topographic features formed largely by the action of surface water.

For this project, you will use the 15 minute raised topographic sheet of the Mammoth Cave Kentucky area.

1. What is the drainage pattern of the northern part of the map? ______________________

2. What is the shape of the cross section of the valley of the Green River? (use the N.W. rectangle, on a line extending from Temple Hill School To Dry Branch School).

   ____

3. Based upon the shape of the river valley, what age would you judge this river to be ? ______________________

4. Follow the course of the Green River. Notice the numerous meanders, some are very sharp, almost to the point of forming ox-bow lakes. What age of the stream do meanders normally suggest? ______________________

5. How do you reconcile the apparent age differences of the river suggested by the characteristics noted in questions 2 thru 4 ? ______________________

The geology of Kentucky is relatively simple. During much of the Paleozoic, this area was covered by a shallow sea. The limestones and sandstones which are exposed today are derived from sediments deposited during the Carboniferous. Sediments deposited during the Lower Mississippian of the Carboniferous were primarily limy muds. Towards the end of the Mississippian, sands and some pebbles were deposited. By the Pennsylvanian, the seas had retreated somewhat, the land was exposed and at or near sea level. This area now began to receive clastic sediments consisting of sands, pebbles, and boulders, from streams carrying these materials from active mountain building areas to the east. An abundant plant life was also developing on the land. But the sea would occasionally flood this low lying area, depositing marine sediments. This pattern of deposition is seen today in the rock record by interbedded layers of sandstones, conglomerates, coalified plant remains, and marine shales. See figure 1 for a brief summary of the area's rocks and their relationship to each other.

6. Notice that the map is roughly divided into two sections on the basis of topography. List some of the differences in topography between the north and south areas.

____

____

____

____

The boundary between the two topographical areas is the Dripping Springs or Chester Escarpment. It is an erosional feature. To the north of this escarpment, sandstones are extensively exposed. They are very resistant to erosion, and form the tops of the ridges. Limestones are exposed in the valleys between the ridges. South of the escarpment, the sandstones have been eroded away, the underlying limestone no longer has a protective "cap" and is more easily eroded.

7. Notice the numerous contour lines in the southern half of the map like those in figure 2.

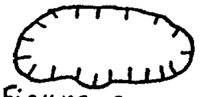

Figure 2

What structures do these contour lines represent? ______________________

8. How do they form?

____

As you read in the introduction, central Kentucky is underlain by one of the most extensive cave systems in the world. It was developed by very normal geological processes, such as solution of the limestone. Solution results from precipitation combining with carbon dioxide, which is present in the air , and in the ground, to form carbonic acid. Limestone is easily dissolved in carbonic acid, producing calcium and bicarbonate ions which are carried away in solution. The water table controls the level at which the major caverns form. This is because precipitation will move downward through the zone of aeration, until it reaches the zone of saturation, when it begins to move laterally. This is when the majority of the limestone is dissolved away, as the water widens cracks and joints in the rock. If the level of the water table changes (i.e. lowers), the cavern is now in the zone of aeration. But in the zone of saturation, the solution of limestone continues. In this way, several levels of caves may form. Mammoth Cave has three major levels of caves which roughly correspond to three former levels of the Green River, and hence, three shifts in the water table level.

Mineral deposits often form in the caves. When water moving downward through the zone of aeration reaches a cavern, droplets will form on the roof. As these droplets evaporate, they form deposits of calcium carbonate, in this way, (9)________ ____________ are built from the ceiling down. Some drops will fall to the floor and evaporate, (10) __________ ____________ are built up from the floor in this way.

Study figure 3. This is an idealized cross section of the three main cave levels.

11. Which cave level(s) would you expect to find stalactites and stalagmites? ______________________________

    (keep in mind that stalactites and stalagmites form by the evaporation of water on the ceiling or the floor of a cavern, leaving a deposit of calcium carbonate behind).

12. Would you expect any of the levels to contain just stalactites? ______________________________

13. If so, which level(s) ? ______________________________

14. At what cave level do you think the water table was at approximately the same level for the longest period of time? ______________________________

    (remember that the longer the water table remains at the same level of elevation, the longer the water has to dissolve the limestone within the zone of saturation).

Generalized stratigraphic cross section of the Mammoth Cave Kentucky Area (adapted from Haynes, 1964).

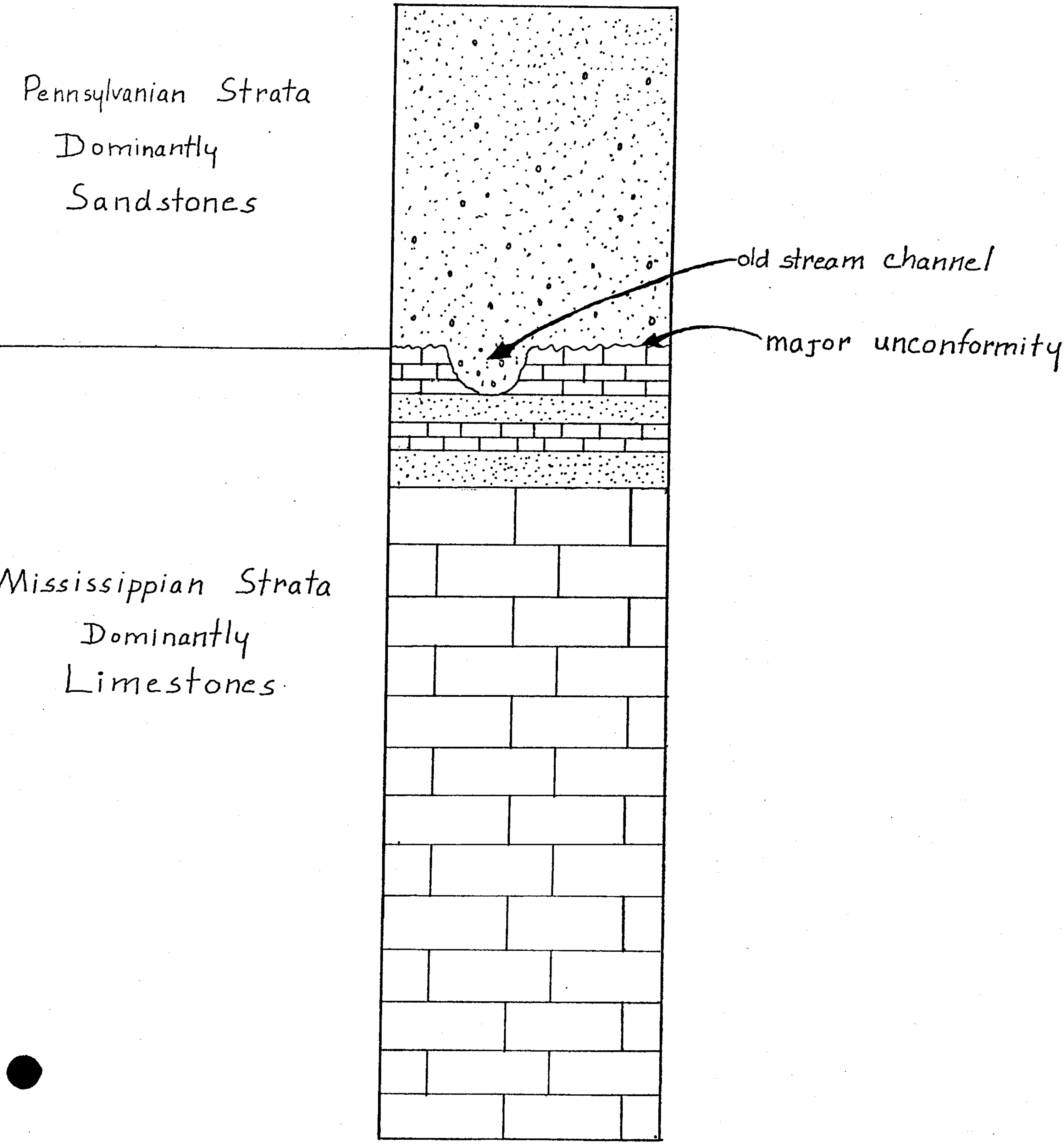

Figure 1

Idealized Cross Section of Cave Levels, Mammoth Cave Kentucky

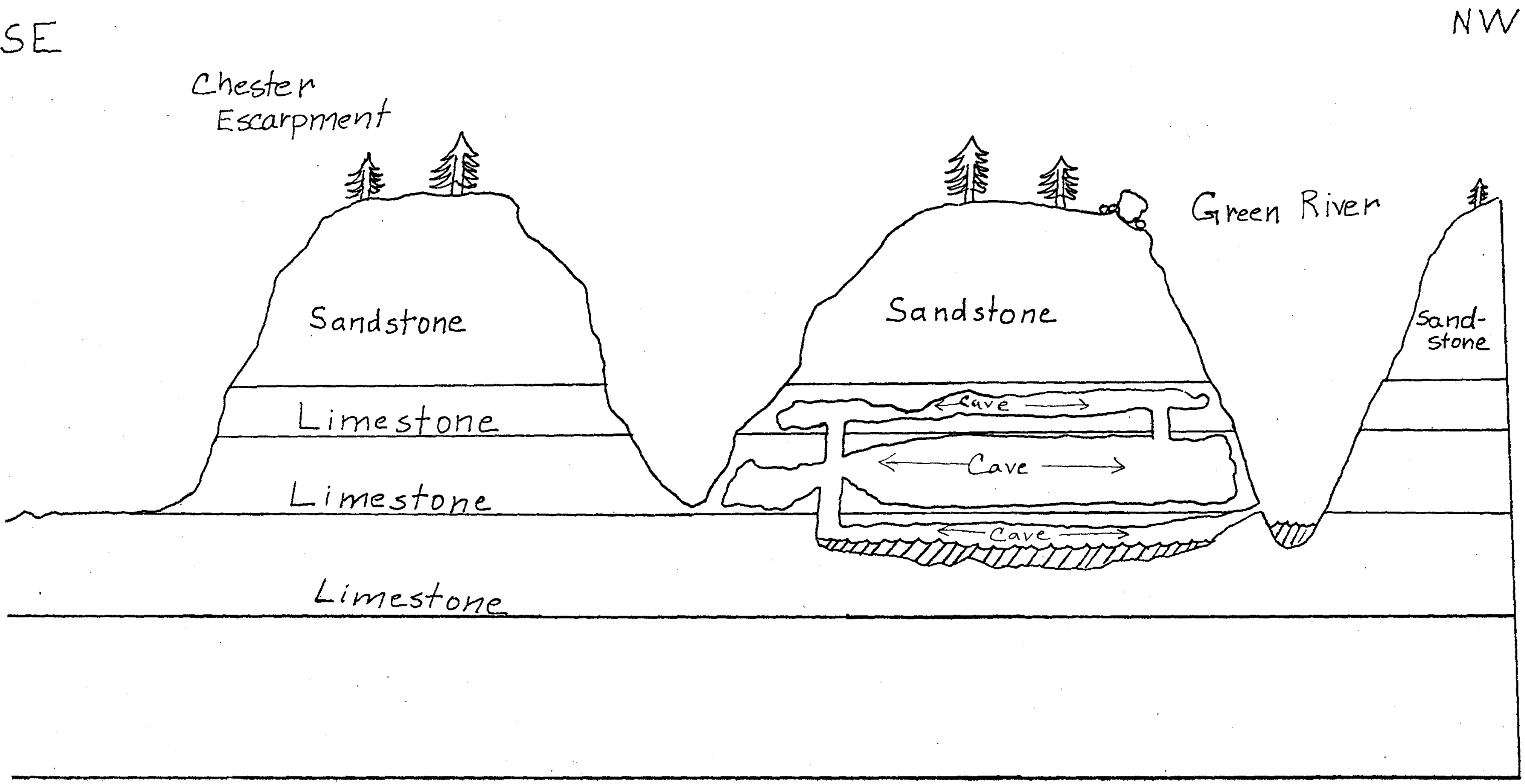

Figure 3

(adapted from Palmer, 1981)

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